Parasolid and D-Cubed for AEC software

SIEMENS

White Paper

The business drivers behind the increasing integration of solid modeling and constraint solving into AEC applications

The market for architecture, engineering and construction (AEC) software, including plant and structural design applications, requires continuous improvement in functionality, reliability and value.

Siemens PLM Software provides various core technologies as software components to help third-party developers build and improve their software products. This white paper describes the benefits that Parasolid® components and D-Cubed™ components bring to AEC applications. It also provides real-world examples to illustrate how AEC software vendors are currently benefiting from Parasolid and D-Cubed components in their products.

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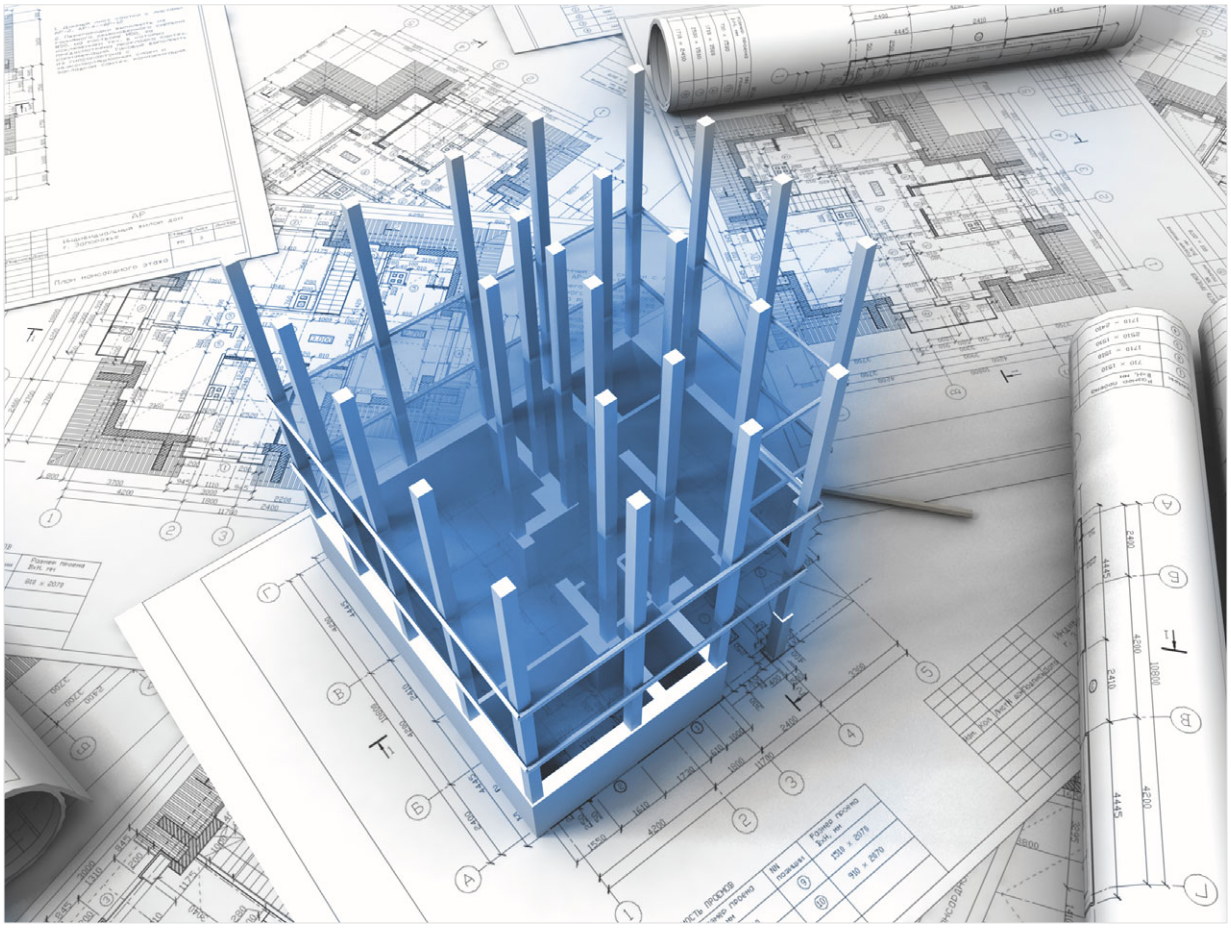
Executive summary

The architecture, engineering and construction (AEC) industry is primarily engaged in planning and designing residential, institutional, leisure, commercial and industrial buildings and infrastructure by applying knowledge about design, construction procedures, zoning regulations, building codes, materials and building techniques.

Many of the world's leading developers of software applications for the AEC industry use one or more Parasolid and D-Cubed components to satisfy their needs for 3D geometry modeling, interoperability and enhanced productivity, delivering superior return on investment and helping to keep pace with the industry's continual need for new capabilities.

A software component can be thought of as a piece of software, developed by a concentration of domain experts, to perform a particularly difficult set of tasks. By marketing the component to application vendors, the cost is shared and all licensees – and their end-users – benefit from greater functionality, performance and reliability than they would be able to achieve themselves. Application developers often appreciate the true value of mature components after they have attempted to solve the problems themselves and fully understand the enormous scale of the challenge. Siemens PLM Software components deliver considerable value to AEC application developers in the following key areas:



3D geometry modeling AEC applications benefit from 3D solid modeling because its unambiguous "master model" principle provides a basis for design and communications between multiple teams and the specialists involved in the build process.

Improved interoperability The teams of architects and engineers that design and execute building projects can collaborate more effectively by sharing data if the software products they use in their domains are based on common industry-standard components.

Enhanced productivity Teams can minimize communication errors and unnecessary rework in AEC projects by using unambiguous models that capture design intent. Teams should be able to make changes easily and propagate them reliably to other teams. Teams that reduce the cost and risk of design changes have more freedom to explore design variations and refinements after the concept stage.

Ability to keep pace with market demands Rather than developing all of their software capabilities from scratch, AEC software vendors can better address customer demands for new or improved features by focusing their product development resources on key AEC functionality and licensing standardized software components from specialized vendors (like Siemens PLM Software). Selective component licensing is a far more efficient business strategy for AEC software vendors.

Siemens PLM Software addresses these four AEC software requirements by offering the following software components.

Parasolid components Siemens PLM Software's leading production-proven 3D geometric modeling component provides the geometry foundation for more of the world's major CAD, CAM and CAE applications than any other modeler. Complementary software components include Parasolid Bodyshop, which provides robust healing technology for imported data and Parasolid Translators for major 3D data formats.

D-Cubed components Siemens PLM Software's suite of components facilitate 2D parametric sketching, 3D dimension-driven design and shape configuration, constraint-based object positioning, collision detection, clearance measurement and hidden-line visualization. D-Cubed components provide vital functionality to most of the world's leading CAD systems and many other applications.

The rest of this white paper discusses the most important business challenges that today's AEC software vendors face and how Parasolid and D-Cubed components have enabled specific vendors to address these issues.

Image courtesy of rolf + hotz architekten Freiburg.

Business challenges

The AEC industry uses a variety of software applications to manage the built environment for residential, institutional, leisure, commercial, and industrial buildings and structures, including building information management (BIM) systems that enable architects and engineers to generate and manage building data across a complex lifecycle.

Typically, this lifecycle runs from requirements definition to design to contractor/subcontractor execution to owner maintenance – with a wide variety of disciplines collaborating as they work on complex building, structural or plant models. Additions and changes need to be carefully aligned and rigorously tracked across multiple lifecycle stages to ensure successful projects, including on-time and on-budget delivery.

While AEC applications require a wide variety of functionality, four key capabilities can be realized by licensing software components from domain experts – thereby enabling AEC software vendors to gain considerable time, cost and resource savings.

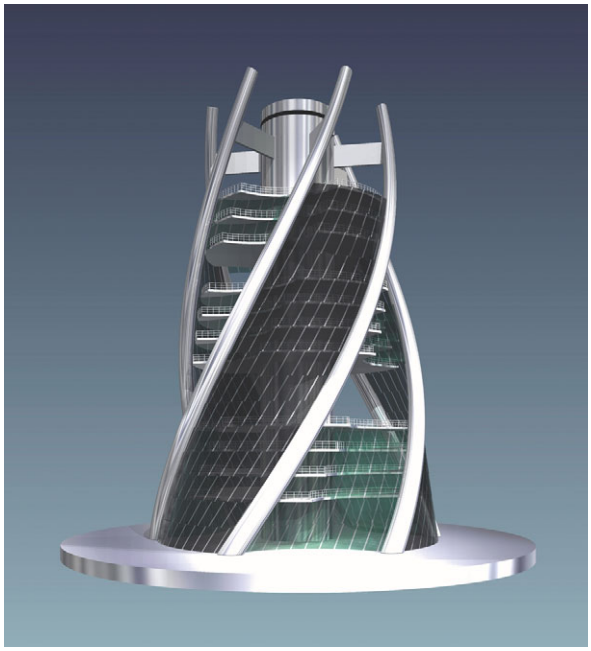


Image courtesy of Paul Oravec.

AEC software requirements met by licensed software components

Requirement	What software components can provide
3D geometric modeling	3D modeling has its roots in mechanical engineering applied to aircraft and automotive product development; it also addresses many of the same requirements in AEC. These parallel requirements include the need to design complex, optimized structures that contain numerous systems and tens of thousands of components simultaneously developed by different teams of specialists. 3D modeling includes a wide array of techniques for rapid design, as well as for editing complex geometric shapes. 3D solid modeling involves the use of a mathematical definition with all of the characteristics of a 3D object. In particular, it defines a fully enclosed and unambiguous space from which properties, such as mass, surface area, center of gravity and moments of inertia, can be calculated. The 3D solid model definition enables designers to easily detect system and structure clashes, as well as thoroughly evaluate and effectively communicate design variations and requirements changes. All applications based on the same solid modeler are able to share the precise design of the "master model," avoiding the delays and errors associated with data translation between disparate applications. Using 3D solid modeling, AEC teams are able to allocate unambiguous "3D envelopes" to teams that work in specific disciplines, such as heating ventilating and air conditioning (HVAC) and mechanical, electrical and plumbing (MEP). This technique provides these teams with total freedom to design within a defined space and use clearly defined interfaces to communicate with other teams, systems and structures. AEC teams can establish complete building models that combine multiple assemblies and include every design detail from door handles to elevator installations. 3D solid modeling systems provide numerous tools for managing and editing multiple instances of components. In addition, the 3D "master model" provides information that can be used to generate up-to-date documentation in traditional formats, including schematics, detail drawings, sections, photo-realistic images or even fly-through animations. Most importantly, this approach provides users with the utmost confidence that they are always working with the latest designs.
Improved interoperability	The building lifecycle requires the participation of multiple teams from different disciplines that generate many kinds of building data, including geometry, material properties, simulations, analysis results, data about spatial relationships, process information and system assemblies. AEC applications need to be interoperable, enabling these teams to seamlessly exchange data between diverse applications. The ability to base different applications in the workflow on the same component technology is crucial for facilitating data exchange without translation.

Requirement	What software components can provide
Enhanced productivity	At its core, an AEC application needs a high performance modeling engine that can deliver constant productivity improvements. The modeling system should enable architects and engineers to capture design intent and maintain it across the entire building lifecycle. It should facilitate and encourage changes throughout the design process. Automated rework of modeling, drafting and analysis leads to lower engineering costs and fewer errors. The more easily and cheaply that changes can be made, the more design variations can be explored.
Ability to keep pace with rising demand	Like all mission-critical systems, AEC applications are expected to provide their user communities with enhanced capabilities on a regular basis. To meet this requirement on a timely basis, AEC application developers need to rapidly integrate new functionality and capabilities into their systems. By licensing software components, which often represent hundreds of man years of specialist development expertise, AEC software vendors can free their own development staff to focus on what they do best: enhancing AEC-specific functionality.

The AEC business case for Parasolid and D-Cubed

Many of the world's leading AEC software developers already use one or more of Parasolid and D-Cubed software components to help meet the requirements outlined above. They include:

- Analist Group
- Autodesk
- Bentley Systems
- CAD Systems
- Intergraph
- Nemetschek Vectorworks
- Planit
- TDCI
- Tekla
- Thermwood
- Vertex Systems

3D geometry modeling

Modern applications for the built environment market, including building information modeling (BIM) systems, require a powerful and reliable geometric modeling kernel capable of handling large quantities of data. Parasolid, the world's leading production-proven 3D solid modeling kernel, satisfies this requirement.

Nemetschek Vectorworks' use of Parasolid in its Vectorworks product line illustrates the value of 3D geometry modeling. Nemetschek Vectorworks, a leading vendor in the AEC market, launched the Vectorworks product suite to leverage Parasolid's 3D solid modeling technology. A key theme of Vectorworks 2009 was the addition and simultaneous release of Parasolid 3D solid modeling functionality in all modules of the product suite, whose solutions are tailored to the needs of architectural, landscape, entertainment and multidisciplinary firms.

"There has been a strong movement towards the adoption of building information modeling within the AEC market," according to Sean Flaherty, CEO of Nemetschek Vectorworks, "The level of interest in BIM is steadily increasing due to the desire to integrate more efficient design practices. However, many are not adopting BIM due to the barriers to 3D use, such as the inability to realize cutting edge, free-form architecture. As opposed to other players in the CAD market who are trying to solve the barriers to 3D with in-house, self-built technologies, we decided to license the absolute best solution in 3D by integrating Parasolid technology. With a purpose-built 3D modeling kernel, Vectorworks 2009 would better manage building complexity, which previously tested the limits of most BIM applications."

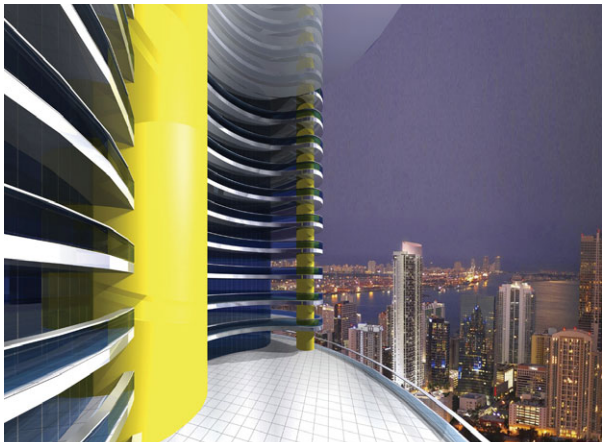


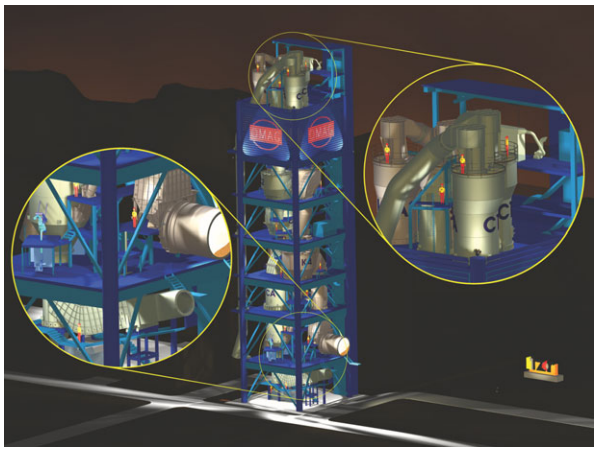
Image courtesy of Paul Oravec.

Another illustration of the same point can be seen in Bentley Systems' use of Parasolid. Bentley Systems provides a comprehensive portfolio of infrastructure applications for the building, plant, civil and geospatial vertical markets, which span both AEC and operations. According to Ray Bentley, executive vice president of the company's platform group, "Some of the most advanced, high-end architects in the world use our MicroStation design software; their buildings are not typical boxes. For example, MicroStation has been used to design the Millennium Dome and the Swiss Re "Gherkin" in London, the renovation of the Reichstag in Berlin and a number of other organic, free-flowing buildings. Many of these structures are based on sculpted surfaces, which you don't find in typical architectural applications."

To support this level of architectural creativity, sophisticated 3D modeling capabilities are required in MicroStation. (MicroStation is Bentley Systems' flagship product, with other applications built on top of it, including Bentley Architecture, Bentley Structural and Bentley HVAC). Bentley decided to license Parasolid ten years ago to provide the core modeling functionality for its software.

"The primary consideration in selecting a modeling kernel at that time was the quality of the modeler," says Bill Bentley, director of software operations at Bentley Systems. "We believe that Parasolid was – and still is – the most reliable and stable modeling kernel on the market." Although some Bentley users still work exclusively in 2D, the vast majority work in 3D, according to Ray Bentley. "We have a larger concentration of 3D users than most PC-based CAD system communities," he says. "And the 3D segment is growing as people are seeing the benefits of 3D in terms of usability and productivity."

But it is at the more geometrically creative end of the spectrum that the strength of Parasolid becomes essential. "It doesn't take much of a solid modeler to design simple orthogonal buildings, but when you get beyond that into the more avant-garde building shapes, it takes a very robust and versatile kernel to handle that," says Ray Bentley. "With our software, users can cut the ends of beams using any arbitrary shape, for example, or make walls with the bottom bigger than the top. They can cut any type of shape in a wall. They couldn't do these things without Parasolid."



Interoperability

AEC and its related applications need to reliably exchange models with other applications. Parasolid enables the direct read/write of the Parasolid native XT file format, eliminating import/export errors.

Parasolid's native XT file format is already supported by many CAD applications, such as MicroStation (from Bentley Systems), NX™ software and Solid Edge® software (from Siemens PLM Software), Vectorworks (from Nemetschek Vectorworks), and SolidWorks (from Dassault Systèmes SolidWorks), among many other systems and solutions. It is estimated that up to 45 percent of 3D designs are stored in Parasolid's native XT file format.

Enhanced productivity

Using Parasolid to enhance productivity. AEC applications require a high performance modeling engine to improve productivity, especially when modeling large or complex projects. The key here is to facilitate design techniques that enable architects and engineers to capture design intent and reduce errors that would otherwise be introduced when manual or unaligned changes are introduced. Just as importantly, AEC application users need to explore design variations more easily.

Nemetschek Vectorworks' use of Parasolid illustrates this point. With a prominent position in the AEC market already established, Nemetschek Vectorworks targeted its Vectorworks Architect 2009 product at architectural firms wanting to explore creative, freeform designs with increased productivity, while retaining full geometric integrity at all times. Since Parasolid offers substantial benefits to Vectorworks' architectural users, it also brings significant speed gains in the entire product suite including Vectorworks Fundamentals, Landmark, Spotlight and Machine Design.

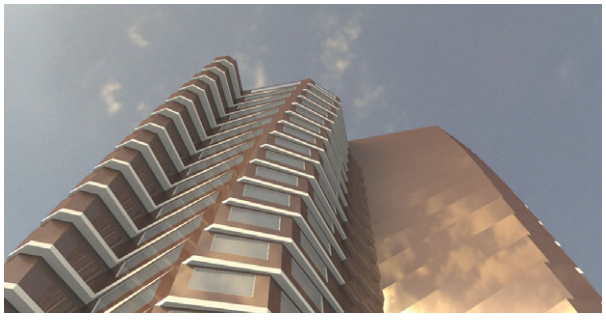


Image courtesy of Nemetschek Vectorworks Inc.

Bentley Systems stresses the importance of Parasolid's high performance modeling engine. Its MicroStation product must be capable of handling very large models. "In AEC applications, you may not have the complexity of some mechanical models, but you typically have a great many more components – thousands and even tens of thousands," explains Vern Francisco, development manager of Bentley System's building products group. "In developing our applica-

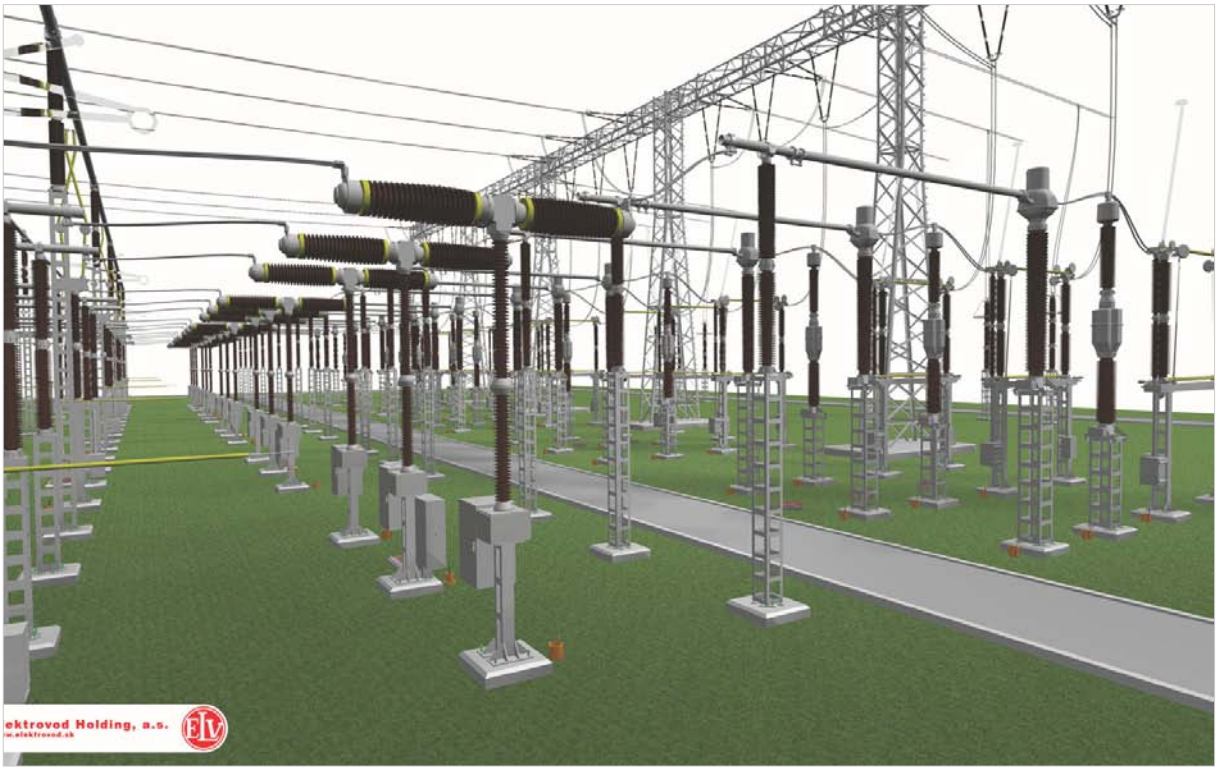
tions, we have to make sure that they are stable even when handling large models."

In addition, one of the most commonly sought benefits of 3D modeling in building design is visualization. "With MicroStation's built-in rendering capabilities, architects and engineers can quickly make accurate photorealistic images or animations that convey the design intent to their customers, and ensure that the design is understood and appropriate before construction even starts," explains Francisco. "It's one of the first reasons designers incorporate 3D into their workflow and it's extensively used."

Another important benefit is the ability to ensure design coordination and constructability while still early in the project, improving the quality and performance of the building and the profitability of the design effort. Parasolid enables all MicroStation users to take advantage of these benefits, while assuring reliable, stable performance even when they create large models.

Using D-Cubed components to enhance productivity. An important facet of BIM systems is the ability to capture and maintain design requirements as the model is constructed and modified. The D-Cubed 2D and 3D Dimensional Constraint Manager (DCM) components are widely used in the CAD industry for enabling this functionality. For example, they allow design intent to be preserved by capturing long-lived geometric relationships between various elements in a 2D layout, or between different structures in a 3D model. Dimensions such as distances and angles can then be modified to explore variations that satisfy the design intent. This parametric design capability is available for the most demanding models, including large designs consisting of complex geometry. A comprehensive range of geometric relationships can be defined – from simple parallel and perpendicular associations to more sophisticated symmetry and pattern constraints.

The 2D DCM powers the sketchers in the majority of today's CAD systems, while the 3D DCM is commonly applied to 3D sketching and controlling the shape and



position of 3D objects. AEC applications can leverage this functionality for a wide range of capabilities, including parametric floor plans, site layout, building design, configuring the shape of libraries of objects (such as windows and doors), steel structure design and assembly and 3D sketching for pipe/HVAC routes.

Autodesk has added parametric drawing, supported by the 2D DCM, to AutoCAD 2010. Arguably the single most widely adopted CAD application in the world, AutoCAD is especially dominant in the AEC market. Autodesk commissioned independent consulting and analyst firm Cambashi to produce the "AutoCAD 2010 Productivity Study" (Copyright 2009 Cambashi Limited. www.cambashi.com/white-papers). As part of the study, a group of practicing architects was asked to perform a typical AEC 2D drawing task to measure the improvements in productivity gained from parametrics and constraints. Cambashi found that "On average, using AutoCAD 2010 took our users 35 percent less time than it took using AutoCAD 2007 for this step." They went on to conclude that "Practices involved in large scale projects that create multiple versions of similar structures, as in a low-cost housing estate or possibly a shopping mall, will find these tools (parametrics and constraints) invaluable."

Nemetschek Vectorworks' use of the 2D DCM component in Vectorworks' design software illustrates how geometric constraint solving strengthens parametric design and BIM functionality. The 2D DCM was integrated in Vectorworks 2010 to improve the computation of architectural layouts by enabling software users to apply geometric constraints appropriate to their high-level design requirements. The end result is a highly intuitive associative design experience with improved performance and behavior, which enhances the creation of intelligent models for supporting BIM workflows.

According to Sean Flaherty, CEO of Nemetschek Vectorworks, "The 2D DCM was the clear choice for a geometric constraint solving platform, offering excellent value, maximum credibility and minimum risk to support the rapid ongoing development of our innovative BIM capabilities. This successful partnership has strengthened our commitment to providing our customers with a superior design experience through sourcing the best available core technologies."

Tekla, developers of comprehensive tools for structural design, also integrated the 2D DCM to extend steel detailing functionality in Tekla Structures.

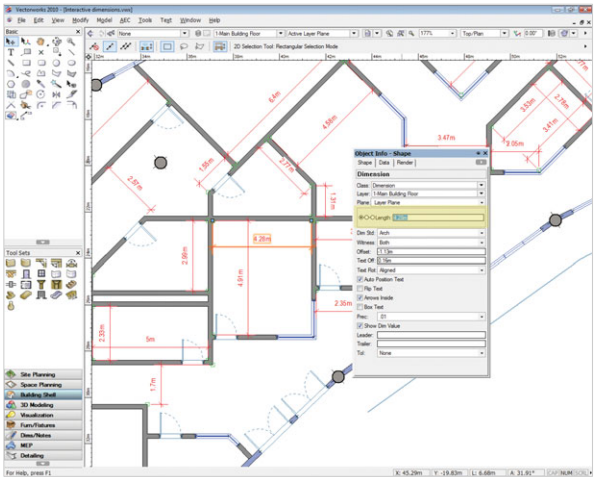


Image courtesy of Nemetschek Vectorworks Inc.

According to Risto Räty, executive vice president for Building & Construction, "Tekla chose the 2D DCM to help us more rapidly achieve our strategic goal of realizing growth in the structural engineering field by delivering better value to customers with Tekla Structures"

AEC applications also need to ensure model integrity. The D-Cubed Collision Detection Manager (CDM) provides a range of collision (interference) and clearance (closest approach) computation capabilities. The CDM is optimized to facilitate rapid computations on large models typical in the AEC, plant and structural markets. These capabilities are especially valuable since they enable AEC applications to eliminate design errors and reduce project rework.

Bentley Systems was looking for a range of benefits when it decided to license the D-Cubed 2D DCM, 3D DCM and CDM components in its MicroStation platform. "The AEC industry is moving in exciting new directions. Technologies such as BIM and Bentley's own Generative Components are vastly increasing the number of design configurations that architects and engineers can explore." says Shaun Sewall, vice president of platform products and technology at Bentley Systems. "Significant design changes can now be made more rapidly, more easily, and more economically than ever before and D-Cubed components are an important part of our strategy to provide advanced parametric design capability to our users."

Keeping pace with rising demand

As today's AEC methodologies evolve, users invariably recognize the limitations of current applications and press the market for additional capabilities and functions. A component approach to application development enables AEC software vendors to focus on delivering new AEC functionality without the substantial cost, and in many cases prohibitive cost, of building the foundational components that underlie their applications.

In other words, Parasolid and D-Cubed components enable AEC software providers to license these building blocks, instead of having to incur the expense of developing and maintaining them in-house.

According to Ray Bentley of Bentley Systems, resources that are not expended on the modeling kernel free the company's developers to focus on continually enhancing MicroStation's world-class AEC functionality. "We don't have to spend our time debugging it," he says. "Also, when we have a problem, the developers at Siemens PLM Software do an excellent job of helping us out. The result is that we don't spend our time diagnosing issues in the kernel that are not our own; Siemens PLM Software will handle that for us."

Efficiency gains from licensing components were also observed by Vertex Systems, a company that develops an AEC application for building design. According to Reijo Havonen, president of Vertex Systems, "By applying several of the D-Cubed components in our new software domain, we have enhanced the design productivity of our Vertex Building Design customers and accomplished this with great efficiency. As we expose more and more of the features of these components over the coming releases, our customers will be able to design their buildings faster and better than ever before."

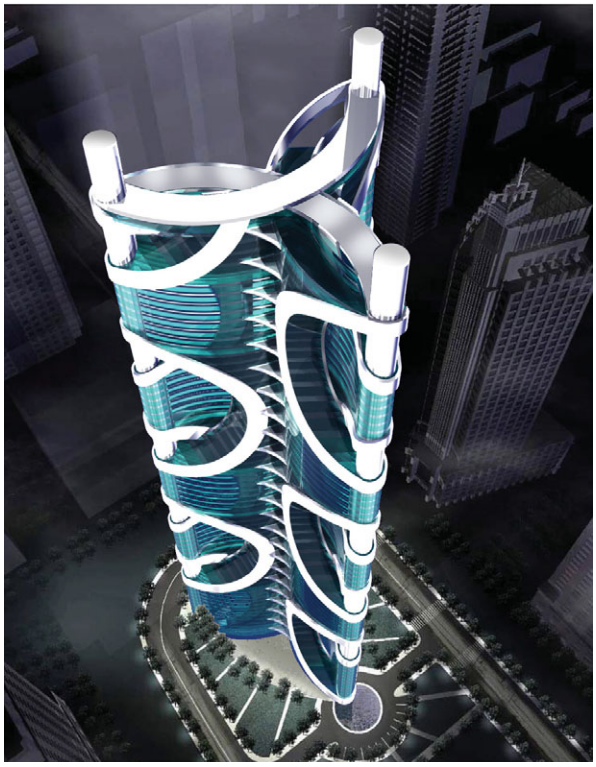


Image courtesy of Paul Oravec.

Appendix

Profiling Parasolid and D-Cubed

Profiling Parasolid

Parasolid is the world's leading production-proven 3D solid modeling component software, providing core functionality that enables users of Parasolid-based products to rapidly and robustly model the industry's most complex products. Based on high precision boundary-representation technology, Parasolid supports solid modeling, generalized cellular modeling and freeform surface/sheet modeling within an integrated framework.

Parasolid's comprehensive capabilities extend to over 850 functions that include a wealth of model creation and editing utilities such as powerful Boolean modeling operators, feature modeling support, advanced surfacing, thickening and hollowing, blending and filleting and sheet modeling. In addition, Parasolid offers extensive tools for direct model editing, including tapering, offsetting, geometry replacement and detail removal with automated regeneration of surrounding data.

Parasolid provides wide-ranging graphical and rendering support, including precise hidden-line and wireframe, as well as versatile tessellation functionality and a full suite of model data inquiries. Parasolid functionality is supported by configurable mechanisms that integrate Parasolid tightly and efficiently into diverse applications.

The global reach of Parasolid-based applications spans multiple industries and has grown well beyond three and a half million end users – all of whom benefit from the ability to seamlessly share geometric models through Parasolid's native XT file format. Parasolid users also benefit from intrinsic, tolerant geometry processing that enables Parasolid to operate successfully with imported data of variable accuracy without loss of robustness. To further boost interoperability for Parasolid-based systems, Siemens PLM Software provides complementary tools that augment Parasolid's intrinsic capabilities:

Parasolid Bodyshop is an add-on component that validates and optimizes the integrity and reliability of imported data using model healing and repair technology.

Parasolid Translators are toolkits that facilitate high-quality data exchange between Parasolid and most major CAD formats.

These technologies combine effortlessly to provide Parasolid users with the most robust interoperability platform available today. By coupling unsurpassed 3D modeling functionality with industrial strength interoperability and proven customer support, Parasolid continues to rapidly expand its market share and enhance its position as the kernel-of-choice for powering the world's premier product development applications.

Profiling D-Cubed

D-Cubed components facilitate key functionality in CAD, CAM, CAE and PLM applications, including sketching, part and assembly modeling, motion simulation, collision detection, clearance measurement and hidden-line visualization. Easy to integrate and compatible with a wide range of modeling systems, D-Cubed components do not require modification of an application's data structure, making them appropriate for both new and mature applications. Most of the world's leading CAD applications include one or more D-Cubed components. The D-Cubed product portfolio includes the following software components.

2D Dimensional Constraint Manager (D-Cubed 2D DCM) The 2D DCM provides a geometric constraint solving capability that enables end-users to create and modify 2D designs, such as floor plans, more effectively. Driving dimensions (parameters) and geometric constraints specify the location of the geometries in a 2D sketch. End-users modify designs by changing dimension values or dragging geometry. The 2D DCM maintains design intent by ensuring that dimensions and constraints are satisfied.

Profile Geometry Manager (D-Cubed PGM) The PGM is used to manage higher-level sketching operations on loops of geometry in 2D sketching environments. The PGM improves productivity, particularly in the areas of profile offsetting and loop constraint operations.

Hidden Line Manager (D-Cubed HLM) The HLM rapidly computes accurate hidden-line views for visualization, drawing plans and technical illustrations of 3D models. Compatible with virtually every geometric modeler, the HLM operates in multi-CAD environments and supports combinations of exact, faceted, solid, surface, wireframe, manifold and non-manifold objects.

3D Dimensional Constraint Manager (D-Cubed 3D DCM) The 3D DCM enables the efficient use of dimensions and constraints to position objects, control their shape and produce 3D sketches. Support for a comprehensive range of geometry, dimensions and constraint types enables designers to efficiently build, modify and animate the most demanding models. As a highly flexible 3D constraint solver, the 3D DCM is also used to directly specify the shape of 3D parts and is the engine behind several of today's most advanced 3D sketching environments.

Collision Detection Manager (D-Cubed CDM) The CDM detects collisions and measures clearances with exceptional accuracy and speed. Compatible with any surface or solid modeler, the CDM operates on exact or faceted geometry. Its excellent performance supports interactive operations on very large models.

Assembly Engineering Manager (AEM) The AEM brings the realistic and interactive motion simulation of objects to the core of a CAD system. The AEM takes account of the mass properties of objects and the forces that act on them, simulating the interaction of objects as they come into contact and transmit motion. Requiring no special preparation by the end-user, the AEM saves time and money by verifying the function of virtual models, reducing the requirement for physical prototyping.

About Siemens PLM Software

Siemens PLM Software, a business unit of the Siemens Industry Automation Division, is a leading global provider of product lifecycle management (PLM) software and services with 6.7 million licensed seats and more than 69,500 customers worldwide. Headquartered in Plano, Texas, Siemens PLM Software works collaboratively with companies to deliver open solutions that help them turn more ideas into successful products. For more information on Siemens PLM Software products and services, visit www.siemens.com/plm.

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